09.15 CWA3

Microdisks with circular photonic bandgap boundaries exhibiting high-quality low-order modes

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Novel microcavities are fabricated that consist of GaAs microdisks (~3 μm diameter) sandwiched between AlAs cladding, bounded by a circular grating of deeply etched air trenches. An emitting layer of InAs quantum dots is inserted in GaAs. The grating acts as a 4th-order Bragg reflector for the in-plane cavity, so that some 2nd-order diffraction towards air can occur. This allows to observe upwards the horizontal resonances through the mode leakage.

Microdisks modes usually require high azimuthal number l to be confined through total internal reflection, while drum-like modes with low-azimuthal number l only see the poorer normal reflection at the semiconductor-air interface (30%). In our cavity, the circular Bragg mirror is highy reflective for these low-l modes. Peaks with Q's up to 650 are observed, and modes are tentatively identified up to l=6. The cavity finesse peaks at 50, corresponding to a reflectivity in excess of 85%.

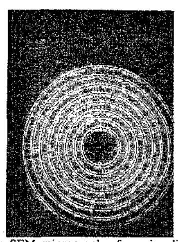

Fig. 1 : SEM micrograph of a microdisk. The inner disk diameter is 2.8 μm and the grating period is Λ=640 nm.

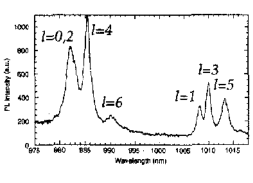

Fig. 2 : Observed peaks in the spectrum collected from the grating area and their azimuthal order l.

09.30 CWA4

Photonic crystal microcavity enhanced LEDs

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One of the main motivations of pursuing research into photonic crystals is to modify the spontaneous emission rate in active material. In particular, the aim is to a) increase the extraction efficiency in LEDs, which is typically around 3-5% in commercial devices and b) to decrease the spontaneous emission lifetime, which is currently in the ns-regime, in order to enable high speed modulation. These goals can be achieved by suppressing the undesired electromagnetic modes into which the emitter can radiate, and by, concurrently, enhancing the desired modes [1].

We studied, theoretically and experimentally, a variety of geometries that are promising candidates for such a microcavity enhanced LED. All structures are based on a thin slab of active InP/InGaAs material into which we drilled (by electron-beam lithography and chemically assisted ion beam etching) triangular arrays of holes. By braking the lattice symmetry, deliberate defects are introduced into the otherwise regular crystal. Such a break in the lattice is caused, e.g., by omitting holes in regular intervals or by increasing the size of the "neck"or "bridge" between selected holes (Fig.1). These defects are points in the lattice where the electric field concentrates, and thus act as microcavities [2]. Our simulation has shown that the defect modes primarily radiate perpendicular to the plane of the 2-D crystal, which is not surprising, albeit very desirable for practical devices. For best emission enhancement, their Q should closely match the Q ($\lambda/\Delta\lambda$) of the active material. The material Q for III-V semiconductors, however, is approximately 20-30 and typically lies below the Q of microcavities formed in photonic crystals. In order to achieve a close match between the material and the cavity, the Q of the microcavity-array can be tuned (i.e. lowered!) by varying the size and type of each individual defect or by adjusting the spacing between adjacent defects. Figure 1 shows an example of a microcavity-array where the defects have been created by increasing the "bridge" between three holes. The defects have been packed very closely together with the intention of creating a broad "impurity band", which is expected to have a lower Q than an equivalent array of isolated defects.

Since fabrication on a sub-micron scale introduces the problem of non-radiative recombination at the exposed semiconductor surfaces, we have also studied the radiative recombination yield in the InGaAs/InP material that is used in the experiments. We found that, by using a combination of wet etching and passivation treatments, the luminescence in the material is sufficient to promise the observation of cavity enhancement in our structures.

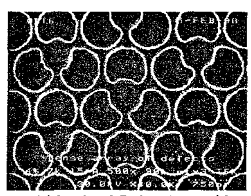

Figure 1 *Top view of a dense array of defects in a 2-D photonic crystal lattice. The kidney-shaped areas are holes that have been etched into the semiconductor material. The lattice parameter (hole-to-hole spacing) is 600 nm.*

[1] E.M. Purcell, "Spontaneous emission probabilities at radiofrequencies", Phys. Rev. 69, 681 (1946).
[2] T.F. Krauss, B. Voegele, C. Stanley and R. M. De La Rue, "Waveguide microcavity based on photonic microstructures", IEEE Phot. Tech. Lett., 9, 176-178 (1997).